FEED RESOURCES

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Darag A., El Moulah Fald, De Zborowski Isolde. 1993. Feed resources. In : Livestock production and sahelian rangelands potential: Republic of Sudan = Élevage et potentialités pastorales sahéliennes : République du Soudan. Darag A., Lamarque Georges. CIRAD-IEMVT - FRA. Wageningen : CTA-CIRAD-IEMVT, 19-20. ISBN 2-87614-088-8

The feed value of the open range is related to its diversity in time and space. Each vegetation formation develops during the course of a more or less long growing season, during which quantity increases towards a maximum biomass subsequently to become poorer in quality and quantity while at the same time being subject to attack by animals. Changes are quantitative, whith an annual cycle that is closely related to the rainfall but also to the number and type of animal that is making use of it. Changes are in addition qualitative, the plants being more or less capable of providing the nutritional requirements of the animals depending on their phase in the developmental cycle. Some plants are preferred by cattle, some by camels, and others by sheep or goats, each of which makes a selection of those plants best suited to its needs.

Data from the Sudan on the amount of feed and its nutritional value in each of the vegetative formations are relatively rare. Data are available for small areas only and have not been treated in a manner that would provide an estimate of the overall national feed situation. This present synthesis therefore draws on experience and information from other dry tropical countries and from general figures on nutritional values in order that a comprehensive picture of Sudan's feed resources can be presented. The main sources of information are the data available in the manifold publications on the Sahelian zone of the **CIRAD/EMVT**. This will supply the users of this atlas with useful data on the management of range resources. It needs to be borne in mind, however, that these figures are only indicative and may vary very much in relation to local conditions.

Feed quality

Most data on the Sudan use the figure for Total Digestible Nutrients (TDN) as the expression of feed value. The basic calculation assumes a feed of 95% dry matter with the TDN being equivalent to 31,4% of the dry matter and an annual feed requirement of 1 044 kg of TDN per cattle TLU. This method only takes into account the energy requirements and provides no information on the protein needs of the animals. In addition no account is taken of the seasonal variation in feed value which allows very high levels of animal production in the rains but induces great physiological stress during the dry season. It is thus evident that an analysis of the annual feed situation needs a very much more detailed treatment.

Animal needs

Energy and protein requirements will be dealt with separately. Energy is expressed as Feed Units (FU), equivalent to that of 1 kg of barley and are related to TDN in the ratio of the net energy provided by 1 kg feed to that of 1 883 cal present in 1 kg of barley, that is:

Feed units (FU) = 3.65 TDN (g/kg) - DM (g/kg)/1 883.

The daily feed requirements of one TLU of 250 kg are about 2.3 FU for maintenance, 0.6 FU for a daily walking distance of 10 km plus those required for production equivalent to 0.4 FU per kg milk and 2.4 FU per kg live weight gain. An animal producing 1.5 kg of milk or gaining 250 g per day would thus require 3.5 FU per day or it would lose weight.

At least 150 g of digestible protein are needed for maintenance, 500 g per kg of live weight increase and 60 g per litre of milk produced. The ratio DP:FU provides a good indication of a feed's value. The best ratio for cattle is 110, no production is possible if it is below 80-90 and it should not be less than 50: small ruminants are generally more demanding with the optimum ratio being 130-140 and a minimum of 70-80. Camels probably require a ratio similar to that of goats and sheep.

Another method of calculating the feed requirements of an animal is to calculate the minimum values of the feed which will provide them with an adequate amount of nutrients, in the knowledge that a TLU can eat about 6 kg of dry matter per day. Thus each kg of feed must contain at least 0.5 FU and 25 g digestible protein for maintenance alone and 0.6 FU and 45 g DP are required even at minimum production levels. This paragraph does not pretend to be a treatise on animal nutrition but the figures quoted need to be borne in mind when attempting to evaluate the feed resources of the Sudan.

Grass quality

The quality of different areas of rangeland varies enormously, as for example, in the hyper-arid north where the grasses are mostly annuals to the more humid south where an increasing proportion of perennials are present.

A typical example of an annual grass is provided by *Aristida*. At the beginning of the growing season the plants contain a lot of water and only 25% dry matter but that dry matter is high in protein which may be more than 10%: with a feed value of 0.6 FU and a DP/FU ratio greater than 100 this provides a feed of very high quality. Its quality diminishes, however, as the plant starts to flower, often after only 40-50 days of growth, and at this stage the grass is not capable of providing an animal's minimum feed requirements. By the beginning of the dry season Aristida contains no digestible protein at all and is also low in energy.

In the Sahel or semi-arid zone the development cycle of annual grasses is slower, the energy value of older plants (while still being poor) is better than of those in the very dry areas but there is still a lack of protein.

Perennial grasses such as *Panicum turgidum* and *Andropogon gayanus* are able to provide adequate amounts of energy over longer periods but they also lack protein.

In general grasses are high in energy and adequate in protein for only limited periods of the year and at early stages in their development cycle **(Table 1)**. For most of the year animals can not obtain an adequate diet from grasses alone, even if they select only the best that it is available.

Herb quality

Pastoralists and livestock owners are fully aware of the feed value of the non-grass components of the field layer. For example, cattle refuse to eat *Blepharis linariifolia* when it shoots to its spiny flowering heads but it is a favourite feed for camels and sheep at this stage when the seeds are in the heads.While the plant does not usually form an extensive single-species stand, and **Harrison** and **Jackson** (1958) noted that herds often had to move long distances in search of it, it is a valuable feed constituent which maintains a protein content of 25-50 g DP/kg DM throughout the long dry season when feed quality is generally poor.

Leguminous species are also a good source of protein.In Kordofan, pastures that contain *Cenchrus, Indigofera oblongifolia, Rhynchosia* and *Tephrosia* are used throughout the year, even though sheep usually avoid grazing areas containing *Cenchrus* as the seeds stick in their fleece (**Baumer**, 1979). *Indigofera* and *Tephrosia* are little grazed during the rainy season but become extremely important sources of protein in the dry season, having a feed value of 0.6 FU and 30-70 g DP in each kilogramme of dry matter. The very widespread legume, *Zornia glochidiata*, particularly common on sands in run-on areas and slight depressions where water collects in the rains has a feed value of 0.70 FU and more than 100 g DP/kg in the green state and still contains more than 25 g DP in the dry season even though at this time it has lost most of its leaves.

Some other examples of herbs that have good protein contents **(Table 1)** include *Borreria* spp., *Tribulus* which is a recumbent plant with a very short cycle and contains 10-15% DP, the cucurbits such as *Citrullus,* and *Commelina* (140 g DP/kg) and *Trianthema* (200 g DP/kg). The *"gizu"* is a very good example of a protein-rich pasture, this fact in large part explaining its excellent value as a feed resource.

Table 1 - Proximate composition and feed value of some common Sudan grasses, herbs and crop residues at various stages of growth

Plant type and species	Growth stage	Dry matter (%)	Feed component (% of DM)				
			CP	Fibre	Ash	DP	Feed Units
Grasses							
Andropogon gayanus	early growth	28.0	11.0	31.0	8. 1	6.5	0.67
	flowering stage	27. 4	8.6	31.8	8.8	4.1	0.64
	regrowth, 2 months	29.0	4.2	39.7	5.8	0.1	0.44
	regrowth, 1 month	33. 4	11.0	30.5	8.3	6.5	0.68
	seeding stage	49 .1	3.5	36.8	5.2	0.0	0.55
	dry leaves	90.6	2.4	38.5	6.9	0.0	0.47
Aristida	early growth	25.8	10.8	33.5	9.8	6.1	0.58
adscensionis	flowering stage	32.1	7.4	35.4	9.1	2.9	0.53
	seeding stage (dry)	87.3	5.2	39.5	9.6	0.7	0.38
	dry season	93.7	2.1	45.6	8.0	0.0	0.18
Aristida	early growth	27.1	8.7	35.3	10.1	4.3	0.51
funiculata	flowering stage	51.3	4.7	38. 5	7.9	0.2	0.46
	seeding stage	60.0	3.9	39.5	6.8	0.0	0.44
	dry season	92.8	2.5	42.6	9.0	0.0	0.29
Aristida	early growth	22.6	13.3	31.1	9.1	8.8	0.66
mutabilis	flowering stage	32.5	7.2	35.6	8.0	2.7	0.54
	seeding stage	58.3	4.5	39.3	6.8	0.0	0.44
	dry season	93.6	3.2	41.7	6.6	0.0	0.35
Cenchrus	early growth	23.0	15.0	30.3	11.8	11.5	0.63
biflorus	flowering stage	25.1	8.8	33.2	10.9	4.3	0.57
	seeding stage	39.2	5.4	38.8	9.2	0.9	0.41
	dry season	87.4	3.5	39.2	9.9	0.0	0.39
Dactyloctenium	early growth	28.6	9.4	29.4	7.0	4.9	0.75
aegyptiacum	flowering stage	26.7	7. 8	32.3	8.8	3.3	0.63
	seeding stage	39.9	6.7	34. 9	7.1	2.2	0.58
Eragrostis	pre-flowering	45.6	6. 9	34.5	4.7	2.4	0.65
remula	seeding stage	60.2	3.8	37.0	3.6	0.0	0.59
	dry season	94.1	1.2	41.3	5.5	0.0	0.41
Hyparrhenia rufa	early growth	27.5	10.6	30.4	7.0	6.0	0.63
	regrowth, 2 months	39.0	7. 6	31.9	14.5	3.1	0.55
	full development	54.0	2.7	35.4	11.1	0.0	0.49
Panicum turgidum	flowering stage	34.1	9.7	31.7	7.8	5.2	0.67
	seeding stage	33.8	6.0	35.4	7.2	1.5	0.57
	dry spikes	54.7	2.7	38.5	7.7	0.0	0.46
	dry leaves	87.2	3.1	39.4	6.1	0.0	0.45
Schoenefeldia	early growth	26.2	8.7	34.9	8.0	4.2	0.56
gracilis	flowering stage	33.2	6.3	36.0	8.9	1.8	0.52
	seeding stage	50.5	4.1	37.3	7.6	0.0	0.49
	dry season	92.7	1.6	41.9	7.8	0.0	0.32
Herbs							
Blepharis	early growth	18.7	22.1	14. 7	13.9	17.8	
linariifolia	flowering stage	30.4	9.4	18.9	11.2	4.9	
	seeding stage	73.8	6.9	22.4	5.9	2.4	
	dry season	94.7	7.3	25.7	13.5	2.8	
Borreria spp.	flowering stage	21.3	8.4	27.0	7.7	3.9	
	seeding stage	36.9	7.1	27.6	10.8	2.6	
	dry spikes	86.6	8.3	26.8	10.5	3.8	
Citrullus	flowering stage	15.4	6.6	13.7	21.6	12.1	
colocynthis	with fruits	20.3	14.4	21.9	12.6	9.9	
Cyperus	early growth	25.3	11.3	27.1	8.7	6.8	
conglomeratus	flowering stage	34.9	5.2	30.8	8.2	0.7	
	dry season	94.0	3.5	35.1	6.8	0.0	
Indigofera spp.	early growth	21.6	17.3	17.7	10.5	12.8	0.85
	flowering stage	30.2	10.4	37.0	13.3	5.9	0.43
	seeding stage	36.6	11.1.	26.1	10.7	6.6	0.71
	dry season	91.2	6.7	28.3	11.6	2.2	0.76
Tribulus	early growth	23.4	18.5	22.5	14.1	14.0	
terrestris	flowering stage	25.6	15.6	26.3	19.3	11.1	
Zornia	early growth	19.1	18.7	24.9	9.7	14.2	0.74
glochidiata	flowering stage	32.1	16.0	27.7	6.6	1.5	0.74
	seeding stage	33.2	13.4	29.7	7.1	8.9	0.69
	early dry season	93.6	13.2	30.2	9.6	8.7	0.65
	late dry season	95.5	6.9	37.9	3.9	2.4	0.53
Crop residues							
Millet	stalks	85.0	5.6	41.4	7.4	1.9	0.36
Rice	stalks	92.3	3.2	38.0	17.7	0.0	0.42
Sorghum	stalks	77.4	3.9	40.3	9.0	0.0	0.30
Maize	leaves	85.9	3.8	38.6	4.3	1.4	0.27
Groundnuts	leaves	89.8	8.6	43.3	9.3	3.4	0.30
Sugar cane	eaves	68.0	2.7	39.8	5.4	0.0	0.44

Browse

Even though many herbaceous plants contribute to increasing the feed value of the feed layer when grasses have dried out they are not present in sufficient quantity to be capable in themselves of providing an adequate ration. Most protein is thus obtained from browsing trees and shrubs, including their green or dry leaves, flowers, fruits and young twigs. All the domestic species, but particularly camels and goats, eat some browse, the proportion increasing as the quality of the field layer diminishes.

An indication of the feed value of browse can be had by looking at the composition of some *Acacia* species. The green leaves contain 110-130 g DP/kg DM and they also have an energy value of 0.8-0.9 FU. Even dry leaves that have fallen to the ground have a protein content of some 6% and the small new shoots have a similar value. Herdsment often reserve the pods of leguminous trees for use by lactating females, a rational practice when it is realized that the seeds contain 20% DP. Branches are often cut from trees (particularly from *Acacia seyal* on waterlogged soils) to make this kind of feed more readily available to animals. Overuse of this technique during the recent drought years has unfortunately contributed to the disappearance of many trees, even though these are basic to animal survival in many areas.

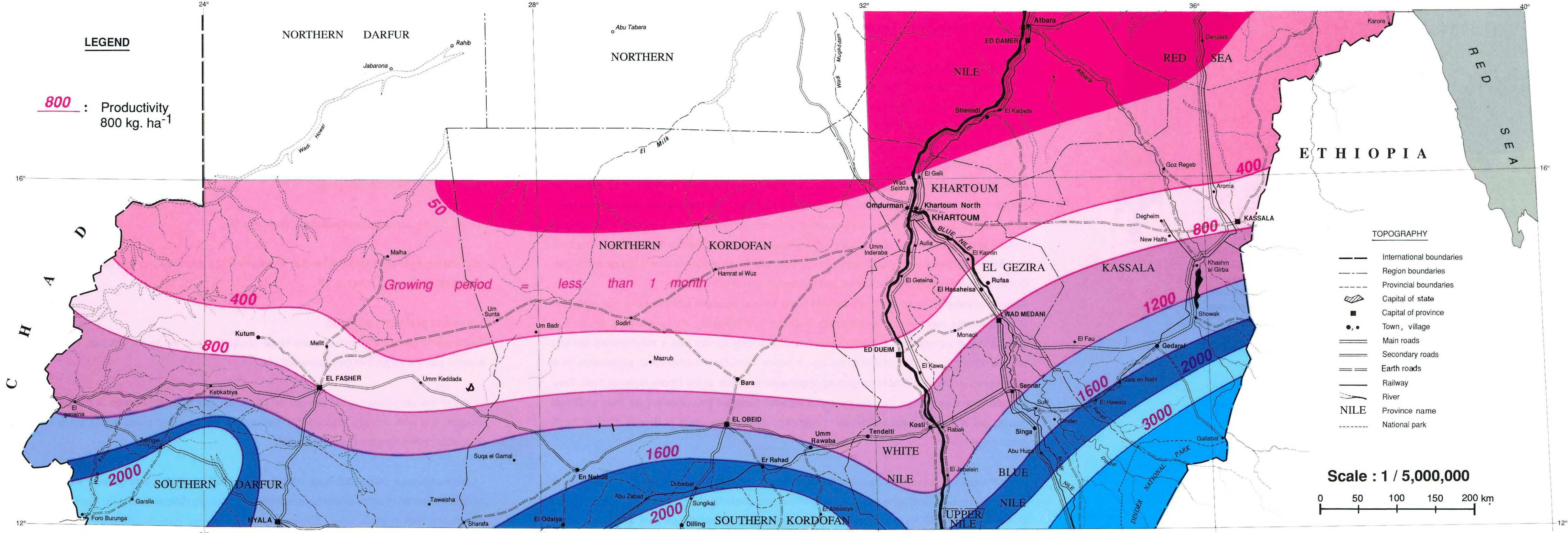
Leguminous species are not, however, the only trees of good feed value **(Table 2)**. The Capparidaceae are also important in this respect and are actively sought out: they are fairly resistant to direct browsing and when cut for feed they assume the characteristic appearance of a thight ball of dense twigs. Almost all the Combretaceae are also eaten willingly and it would in fact be true to say that almost no tree is totally ignored. Even *Calotropis procera*, supposedly not eaten, will be sought out by cattle in extreme cases of feed shortage.

Most woody species contain more than 50 g DP/kg DM but the energy values generally quoted **(Table 2)** should be treated with some circumspection as digestibility often interferes with proper absorption.Tannins and phenolic compounds often reduce digestibility but there is still a lot of work to be done before firm statements can be made about the real effects of these compounds. Within the context of a mixed and complex feed supply, however, the value of browse has to be considered as being very high.

Table 2 - Proximate composition and feed value of some common Sudan trees and shrubs at - various stages of growth

Species	Growth stage	Dry matter (%)	Feed component (% of DM)				
			CP	Fibre	Ash	DP	Feed Units
Acacia nilotica	green leaves	37.8	16.7	10.8	7.1	12.2	
	dry leaves	90. 1	11.2	12.4	6.2	6.7	0.84
	green pods	40.4	11.2	13.9	4.4.	6.7	
	dry pods	90.8	9.8	18.4	4.5	5.3	
Acacia raddiana	green leaves	37.9	17.8	17.0	7.4	13.3	0.94
	young twigs	32.5	16..2	28.2	6.0	11.7	0.74
	green pods	31.0	14.1	21.8	6.8	9.6	
Acacia senegal	green leaves	43.3	16.0	12.1	6.6	11.5	0.85
	dry leaves	88.4	18.2	11.2	8.4	13.7	0.71
	dry pods	91.9	24.2	22.8	7.3	19.7	
Balanites	green leaves	44.2	12.9	13.9	15.7	8.4	
aegyptiaca	twigs and leaves	50.0	11.9	17.3	14.0	7.4	
	fruits	68.5	11.2	10.1	8.1		
Cadaba spp.	green leaves	40.3	22.5	13.1	19.7	18.0	
	leafy twigs	54.8	9.1	24.6	9.8	4.6	0.68
Combretum	green leaves	32.0	13.0	12.2	6.5	8.5	
glutinosum	older leaves	52.2	8.6	18.7	6.1	4.1	
	dry leaves	92.2	11.4	27.2	7.2	6.9	
Acacia albida	green leaves	30.7	17.8	17.5	6.4	10.3	
	dry leaves	92.8	11.7	21.4	4.1	7.2	0.88
	pods	89.4	11.8	19.6	4.0	7.3	
Guiera	dry leaves	95.5	9.3	22.0	6.2	4.8	
senegalensis	young twigs	37.9	28.8	15.4	5.0	24.3	
Leptadenia	green leaves	21.0	13.9	14.7	15.6	9.4	
pyrotechnica	tiwgs	31.6	8.6	42.3	7.2	4.1	
Maerua	green leaves	44.0	22.5	8.4	18.9	18.0	
crassifolia	leafy twigs	41.7	23.6	10.9	16.5	19.1	
Pterocarpus spp.	young leaves	28.4	21.2	17.0	7.7	16.7	0.88
	older leaves	37.5	12.1	27.3	6.7	7.6	0.74
	dry leaves	90.5	10.3	31.5	7.4	5.8	0.51
Sclerocarya	young leaves	25.0	10.5	13.4	10.7	6.0	
birrea	dry leaves	95.9	5.7	20.2	16.5	1.2	
Tamarindus indica	green leaves	32.1	11.4	17.8	7.4	6.9	0.67
	pods	92.5	8.4	12.6	4.4	3.9	
Ziziphus	young leaves	33.0	19.4	11.2	8.4	14.9	
mauritiana	leafy twigs	92.6	12.2	20.6	7.9	7.7	

PRIMARY PRODUCTIVITY AND FEED RESOURCES



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Crop residues

Crop residues provide another source of animal feed. The livestock of mixed farmers, and occasionally of pastoralists, have access to crop residues after the harvest. Feed values are usually low, of the order of 0.3 FU/kg DM, and the residues also usually contain little or no digestible protein. The exception to the general rule is provided by the haulms of groundnuts, which have a generally higher feed value, advantage being taken of this to sell them, especially in and around the larger towns. When efforts to conserve crop residues are made they are rarely stacked or stored properly and further losses in feed value occur, such that they are only of similar nutritive value as dry grasses when they are finally fed.

In irrigated areas there is some possibility of better nutrition, especially of protein, from the regrowth of weeds and crops in the fields and from the growth on canal banks. Even here, however, as well as in dryland farming areas, it is necessary to provide some concentrate feed or some agro-industrial by products, to ensure a satisfactory ration.

Minerals

Theoretical requirements for the two major elements are met when the feed resource contains more than 0.3% of calcium and 0.2% of phosphorus. These requirements are usually met for calcium as grasses contain 0.26-0.50% when young and about 0.35% at later stages. Phosphorus contents of herbaceous species (including non-grasses), on the other hand, are usually of the order of 0.10-0.20% in the early growth stages and are reduced to less than 0.1% at later stages. Phosphorus deficiencies are unfortunately not overcome by browse as these species also usually contain only 0.07-0.15% of the element.

Crop residues are low in both calcium and phosphorus but some by-products (such as oil seed cakes) and grains have higher levels of phosphorus of 0.3-0.6% or, as in the case of cotton seed cake, even up to 1.2%.

In general it can be considered that phosphorus nutrition is inadequate on most pastures and that in many areas minor and trace elements will also be deficient.

Feed quantity

It is difficult to estimate the productivity of arid tropical rangelands for several reasons. First of all, as already stated, the growing period is very short and does not allow of several measurements. Interannual variations are very large in relation to the variations in rainfall. In addition, the problem is accentuated for trees and shrubs whose productivity is notoriously difficult to estimate or measure. In the particular case of the Sudan, the droughts between 1974 and 1984 have also made it difficult to apply regular formulae for estimating production of vegetation types, as the composition of some of these has changed over this period. This section therefore only attempts to indicate some orders of magnitude of range production in the Sudan, based on a knowledge of various production factors and how they are affected by other factors.

Net primary production

Most available data relate to the maximum standing crop biomass either at the end of the rainy season or at the beginning of the dry season. This figure in itself results from that which has been produced during the growth period, less that which has already been eaten (not only by domestic stock but by such other consumers as rodents and insects) or lost and is thus lower than actual production. Domestic animals, during the course of the rainy season, thus have available to them more feed than is apparent at the end of it, even on reserved areas. If, on the other hand, they graze an area later there is only a (usually unknown) proportion of the original production left to them.

Several methods are available for the calculation of primary production. The simplest is to consider the rainfall as the basic factor in vegetative growth and to calculate productivity as a direct function of total rainfall: several methods are available to do this and these usually estimate primary production at 400 $^{+}$ 100 kg DM/ha at 200 mm of rain and at 1 500 $^{+}$ 500 kg at 400 mm of rain per year although differences exist in productivity at any given rainfall level for various soil types. Another method is to use the growth period in place of the actual amount of rainfall as this takes into account the properties of the soil and its moisture content: for the same rainfall, therefore, production can be calculated for sand or clay soils and for topographic situation. The second method is obviously more useful for the Sudán in this study in view of the approach that has been adopted in defining the agroecological zones.

Suggested values of daily production in relation to soil factors, including fertility and depth, expressed as kg DM per ha are 5-15 for lithosols or soils low in organic matter, 10-25 for more-or-less developed sandy soils, and 20-35 for alluvial and clay soils and loams with high base-exchange capacities.

Interannual variation

Using the method of calculation just described variations in production are expressed in relation to the growing period. Some examples will serve to illustrate the point.

The growing season at Kassala extends from nought to three months. Zero growth is expected only five times every 100 years. The modal growing period is of one month, this occurring in 35 of every 100 years althought the month may be August (probability = 0.18), July (p= 0.10), September (p = 0.03), or a split period (p = 0.04). The probability of a two month growing period (July-August or August-September) is 0.31, that of a period extending from June-August or July-September being 0.29. From the foregoing it is possible to deduce a weighted average growing season of 55 days.

At Gedaref there is often a four month growing period (p = 0.63), sometimes one of three months (p = 0.27) and occasionally one of five (p = 0.08) or even of six (p = 0.03) months.The average growing period at Gedaref is thus 117 days. At Er Roseires the growing period is usually six months (p = 0.43), sometimes seven (p = 0.19) and sometimes five (p = 0.34) to provide an overall average growing period of 170 days.

The relative variation in the growing period at any site is reduced in proportion to the total rainfall received. At Gedaref and Er Roseires the average growing periods have a variance of 40 days, or variabilities of 23% and 34%, while variability at Kassala is about 90%. The idea of an "average" year does not, therefore, have much meaning where estimations of productivity tend to hide the fact that the situation changes very rapidly from one period to the next.

In spite of the reservations, however, attempts have been made to calculate growing periods for all of the mapped ecozones and to apply daily rates of production to these in order to be able to establish total production on the map opposite and to draw lines of equal average forage productivity on it. It has been assumed that the growing period on clays and in the hill areas is shorter by 10 days than it is on sands and that daily production in the hyper-arid zone is 10 kg, in the hill areas is 15 kg, on sands is 18 kg and on clays is 22 kg.

Production and loss

The only data available relate to recent floristic changes or to changes resulting from the overuse of the range in the middle 1970s. These indicate, for example, that there has been considerable loss of *Panicum turgidum* and that *Leptadenia pyrotechnica* is practically the only plant to have emerged unscathed in Northern Kordofan. Areas mapped in the 1950s (**Harrison** and **Jackson**, 1958) as being *Acacia senegal* savanna woodland are now semidesert and *Combretum kordofanum* is currently found in the southern part of its former distributional range. *Dalbergia amara* has generally replaced *Terminalia brownii* in these areas but in some places only *Calotropis procera* survives.

A constant feature of recent change has been the gradual replacement of perennial grasses by short cycle annuals. This is a common change in Kordofan, where it occurred fairly early. It was at first attributed to uncontrolled fires (which used to cover 35% of the area) and to their deleterious effects on the soil through temperature.increases and to reduced infiltration capacity through removal of surface litter, as well as to overgrazing. On soils with unfavourable moisture status it is not now possible for perennials to establish themselves in the short growing period available and only some short season annuals are able to survive and produce.

When one considers, however, that fires are only possible in the savanna woodland areas where there is an adequate biomass of combustible material, it can be seen that fires are of little consequence in the arid and semi-arid areas. Satellite imagery (both NOAA and LANDSAT) shows continuing degradation of the dry rangelands, however, over an area of some 650, 000 km2, or approximately 25% of Sudan's total area. Continuing degradation is explained by the fact that pastoralists are still making their seasonal migrations, in spite of the improvements in climatic conditions, and have a tendency to travel farther and farther south. The lack of feed availability leads to a high mortality and especially to high levels of morbidity which greatly reduce the secondary productivity of the national herd.

In parallel with the degradation of the rangelands it must be remembered that their area is also being reduced in the arid and semi-arid zones as a consequence of the expansion of cultivated areas. In addition the concentration of pastoral populations in the better-endowed areas, for example in river valleys, and around towns which provide the opportunity of additional feed resources contribute to the general degradation. The expansion of rainfed agriculture, on the "*qoz*" as well as on the clay plains, means that the chances of the rangelands ever producing at the level they were at 20 years ago, in terms of both quality and quantity, are very poor.

Overall range production

The percentage of an area available to livestock varies among the ecoclimatic zones defined in this Atlas. Rangelands now hardly represent 50% of the total area on clay and 70% of the area on sand in the semi-arid zone, the situation being intermediate in the cultivated hill areas of Darfur. In the arid zone it can be estimated that 10% of the area on clay, 20% on sand and 30% of the highland areas are cultivated or otherwise irrevocably lost to livestock in Darfur. In the Darfur hyper-arid zone almost the whole of the area is still available to livestock, as it is in the north-east of the mapped area.

The large areas of infertile land and those inaccessible because of lack of water have led to the adoption of a conservative estimate of 5 t DM/km2 in the Red Sea Hills. In the other major ecozones it is estimated that range productivity is 10 t DM/km2 in the hyper-arid areas, 40 t in the Northern Darfur hills, 70 t on arid sands, 80 t in the Butana, 160 t in the hilly areas south of 14° N, 180 t on semi-arid sands and 200 t on clay in the southern part of the area. The semi-arid zone produces 29 million tons of feed or 63% of the total, this being twice as much as that produced in the Sahel zone and 12 times as much as the area north of the 200 mm isohyet. The semi-arid zone is thus still by far the major area of feed production for Sudan's livestock.

The feed situation based on the calculations in this chapter for that part of the Sudan covered by this Atlas (that is north of 12° N) is given in**(Table 3)**for each administrative unit. There is good agreement between these figures and those used by thé Range ans Pasture Administration **(Table 4)** which are arrived at by a totally different method of calculation and in spite of differences in the areas allotted to each ecozone in the two methods. The Central Province can be used as an example: the Pasture Administration assigns a nil value to areas accessible to livestock but of poor nutritive value while the calculations for this atlas include them but overall the total estimated production is the same.

Table 3 - Calculated range production by region and ecozone

	Region ('000 km^2)				
Ecozone and soil type	**Darfur**	**Kordofan**	**Central and Khartoum**	**Eastern**	**Northern**
Semi-arid rangelands					
on sand (70% of area)	15 400	44 800			
on hills (60% of area)	43 800				
on clay (50% of area)			32 500	24 000	
Arid rangelands					
on clays (90% of area)			34 200	42 300	
on hills (70% of area)	25 200				
on sand (80% of area)	33 600	64 800	4 800		
Hyper arid rangelands (100% of area)	43 000	90 000	18 000	32 000	59 000
Red Sea Hills (100% of area)				17 000	
Grass production					
mapped area (tonnes x 10^6)	13.57	13.50	9.75	8.59	0.59
mean (tonnes/km^2)	62.82	57.20	76.79	56.65	6.94

Table 4 - Estimated rangeland forage production, 1987 (Range and Pasture Administration)

Region	Usable rangeland ('000 km^2)	Productivity (t/ha)	Total production (t x 106)
Northern	44 200	15	0. 663
Eastern	173 700	30	5. 210
Central & Khartoum	76 000	126	9. 089
Kordofan	214 000	70	14. 981
Darfur	259 000	63	16. 186
Southern	351 200	100	33.122
Total			79.251

Range rehabilitation

The overall effects of range deterioration and degradation have been published by the Sudan Desert Encroachment Control and Rehabilitation Programme (DECARP, 1976) and by the United Nations International Conference on Desertification.

Recommended goals

Several goals for range rehabilitation have been identified:

> introduction of a management system that will adequately maintain a balance between the grazing resource and the livestock population and sustain optimal production without damaging the resource base;
>
> coordinate provision and siting of water resources and use them as an indirect factor in controlling seasonal stock movements in relation to range condition and availability;
>
> control of fire;
>
> survey and inventory of range resources for the production of maps that can be used to plan future development and strategies;
>
> rehabilitation and improvement of denuded rangelands by protection and reseeding.

Strategy for achieving goals

The restoration of the range to its former condition and productivity is recognized as a major undertaking. The strategy of the Range and Pasture Administration is based on an ecological approach and the involvement of the pastoralists and others who are the target population of the improvement programme.

The corrective measures chosen to implement this strategy correspond to the nature of the problem and the prevailing environmental conditions within each ecological zone. The involvement of local populations and practical demonstrations are fundamental to this approach which aims at restoring range productivity and improving the economic condition and welfare of the people. The strategy puts the rangeland into three management zones, each with its own planned interventions.

Zone 1- Semidesert

promulgation of laws prohibiting traditional rainfed cropping north of 13°N.

encouragement of range rehabilitation by protection of denuded range sites, by artificial reseeding and by soil treatment to increase moisture storage.

application of water-harvesting techniques, water spreading and micro-irrigation techniques for food crop production and nursery establishment.

propagation of seeds and seedlings for reseeding, making of shelter belts and sand dune fixation.

construction of fire lines to reduce damage from uncontrolled bush fires.

Zone 2; Low Rainfall Savanna

integration of fodder production in the crop rotations of agricultural schemes and the development of mixed livestock/crop systems.

protection against seasonal fires.

rehabilitation and improvement of range resources in the vicinity of water sources. avoidance of conflict between farmers and pastoralists in both planned and unplanned schemes.

rehabilitation of the southern stock route to increase offtake with a view to restoring the balance between carrying capacity and stocking rates.

Zone 3; High Rainfall Savanna + Flood region

tsetse control.

introduction of mixed ranching systems.

application of prescribed burning for better use of range resources.

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